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CONTENTS

PREFACE

This book introduces various topics related to sensor and instrumentation systems. The topics cover researches and studies of sensors and instrumentation applications from various fields such as biomedical, agriculture, safety, electrical and electronics industries. The topics describe the theory, research work, circuit design, experiments and system measurement especially in sensor applications. The presented topics have been selected to prepare engineering students to design the sensor and instrumentation systems. This book is generally suitable as an accompaniment to laboratory sessions at engineering institutions.

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10

NYPA FRUTICAN RACHIS AS BUILDING ENVELOPE HEAT INSULATOR

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10.1 INTRODUCTION

This research is conducted to investigate the possibility of cellulose in Nypa Frutican Rachis to achieve thermal comfort. As Malaysia was known as tropical country which has hot and humid climate, this research focus on to study the transfer of heat through Nypa Frutican Rachis as a roof. Since only Nypa leaves have been used as a roof and have been applied until now in East Malaysia, this project uses an innovation of Nypa palm by using its rachis that contain chemical material that have lower thermal conductivity value such as cellulose and lignin as a roof or building envelope heat insulator. This paper described the experimental study method by measuring the temperature of outer and inner surface of Nypa Frutican Rachis on small physical model study. The temperature was measured by using Digital Infrared Thermometer. The average outer and inner temperature for five consecutive days was obtained from the experiment is highlighted. Results show that the average of heat loss and heat transfer conduction for five consecutive days are 9.63 W/h and 9.86 W. This experiment shows a good result and proved that Nypa Frutican Rachis is suitable and effective to be a building envelope heat insulator.

Malaysia is known as a tropical country which has warm and humid climate. The average daily maximum temperature is 34^{o}C and the mean temperature is 26.4^{o}C annually. The annual relative humidity value ranges within 74% to 86% [1]. This type of climate will develop a thermal discomfort in the urban environment. Thermal comfort can be achieved as temperature and humidity are important determinants for maintaining a comfortable.

Temperature and humidity impact the 100% saturation with water in the airways and affect the physiologic response to heat. This factor affects the physiologic of any indoor occupant of a house to achieve the thermal comfort. The amount of heat removed from the skin depends on the latent heat evaporation of water and the rate of evaporation which can be mainly determined by the amount of sweat secreted and evaporated [2].

10.1.1 Roof

Roof is the part of a building which experiences the maximum amount of solar radiation and the traditional roof-surface temperature may rise up to 65°C in hot climate which accounts for several disadvantages [3]. The roof ceiling is the most important elements affecting the thermal environment inside buildings because it receives large amounts of solar radiation. A lot of cool roof technologies had been applied in hot-humid climate regions. Traditional Malay houses use lightweight construction of low thermal capacity holds little heat and cools adequately in night [4].

The amount of heat transfer through the roof materials layers will be delayed as the thermal capacity of the layer material is higher. This will result an excessive amount of heat stored inside the layers and a warmer condition for occupants at night. As the amount of heat stored is higher for a material that have high thermal capacity, the time taken for heat transferred out from the material will be also delayed.

10.1.2 Chemical Properties in Nypa Fruticans

The chemical composition of cellulose and hemicellulose contain in the rachis is 32.5% and 22.1% respectively [5]. The rich content of cellulose made Nypa Frutican's rachis look as a suitable material to be a roof as its typical thermal conductivity are between 40 and 50 mW/(mK). The thermal conductivity value (λ-value) of cellulose can be referred to table of bio-based insulation material with other material thermal properties [6].

Nowadays, the usage of cellulose as insulator is widely used. Cellulose insulation is produced to act as a filler material to fill the void created. Cellulose can be an alternative insulator to the fiberglass. Cellulose is eco-friendly, non-toxic and cost-effective thermal solution. The easy access of cellulose also be one of the reasons why cellulose is good for insulator. Cellulose easily can be found in the plants and recycled newspaper [7].

10.2 MATERIAL AND METHOD

A man-made hut is constructed from timber wood for hut's column, beam and roof beam. An unprocessed Nypa Frutican Rachis was design to be cut into 28 cm length, 3.2 cm width and thickness of 1 cm to be as the roof shingles. 18 parcels of Nypa Rachis were collected to carry out the experiment. The temperature of outer surface and inner surface were recorded at 1.30 p.m., 2. 30p.m and 10.30 p.m. by using digital infrared thermometer. All shown in Figure 10.1 to Figure 10.3

10.2.1 Design of the Experimental Small Hut

The experimental hut is made from timber wood for columns, beams, and roof beams. The Experimental Small Hut size area is 0.7 m x 0.3 m. The Small Hut's was applied a modern house's roof concept which has a natural air ventilating system. The roof concept is open conduit to atmosphere where results in no ventilation's purpose.

10.2.2 Nypa Fruticans Rachis as Roof Shingles

An unprocessed Nypa Rachis is collected in Sungai Pagoh, Jorak, Muar. The inner part of Nypa Frond was design to be cut into 28 cm length, 3.2 cm width and thickness of 1 cm. The cut rachis was dried for 3 hours to increase the hardness of the rachis. These materials are arranged side by side neatly so no leakage to roof structure during rainy day and nailed on the roof beams of Experimental Small Hut.

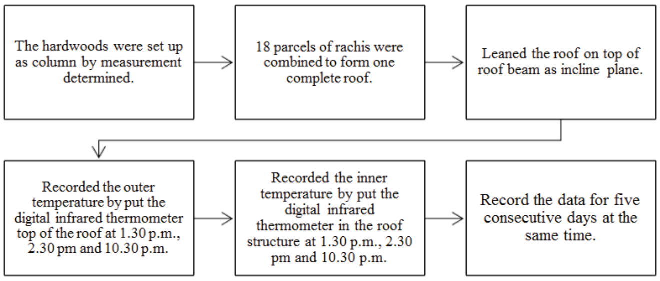

Figure 10.1: Procedure of man-made hut constructing

Figure 10.2: Sample of Nypa Frutican Rachis

Figure 10.3: Complete Man-make hut

10.3 RESULT AND DISCUSSION

In this chapter, the result of Nypa Fruticans Rachis Insulator Surface temperature was recorded and calculated for 5 consecutive days. The inner and outer surface temperature of roof shingles was recorded for 18 shingles that was

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experimentally used in this project. Furthermore, the result analysis for Heat Loss and Heat Transfer by conduction are also calculated and tabulated.

10.3.1 Result of Nypa Fruticans Rachis Surface Temperature

The Table 10.1 and Figure 10.4 shows the average temperature recorded using Digital Infrared Thermometer for 5 consecutive days. The reason average temperature was used for this experiment is because of the varies temperature recorded on both outer and inner side surface of 18 Nypa Frutican Rachis sample.

Table 10.1: Average Outer and Inner Temperature for five consecutive days

Day	Average Outer Surface Temperature (˚C)			Average Inner Surface Temperature (˚C)		
	At 1.30 pm	At 2.30 p.m	At 10.30 pm	At 1.30 pm	At 2.30 p.m	At 10.30 pm
1	35.06	34.94	25.33	31.94	32.94	25.44
2	33.33	37.72	27.60	30.61	34.28	28.17
3	30.11	31.28	27.61	28.44	29.22	28.28
4	42.00	42.50	28.28	36.67	37.28	29.17
5	40.80	37.83	27.61	35.78	35.28	28.22

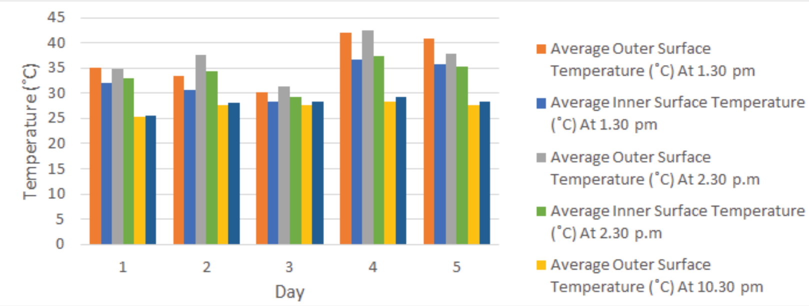

Figure 10.4: Average Outer and Inner Surface Temperature (˚C) versus Day

The highest difference between Outer and Inner surface temperature at Day 1 is 3.12˚C at 1.30 pm. The highest difference recorded in Day 2 is 3.44˚C at 2.30pm while the highest difference at Day 3 is 2.06˚C. Both difference between outer and inner surface for Day 4 and Day 5 are 5.33˚C and 5.02˚C respectively. From this result, we have concluded that Nypa Frutican Rachis is good for insulating material as they recorded amount of heat changes between inner and outer surface from 2.06˚C to 5.33˚C.

10.3.2 Average Heat Loss and Heat Transfer by Conduction - Heat through Cellulose

Average Heat Transfer by Conduction through cellulose and Average Heat Loss in cellulose can be calculated using Equation (1) and Equation (2) respectively. The analyze data recorded as below with R-value = 0.256;

$$Q = \frac{kA\left(T_{out} - T_{in}\right)}{d_m}$$

(10.1)

Where,

Q = Conduction Heat Transfer (W)
k = Materials Thermal Conductivity (W/m K)
A= Cross Sectional Area (m ^{2})
T_{hot} = Outdoor Temperature (˚ C)
T_{in} = Indoor Temperature (˚ C)
d_m = Thickness of Material

$$\text{Heat Loss} = \frac{A \times \theta T}{R - value} \tag{10.2}$$

where,
A = Area of shingle (m)
θT = Difference in temperature (˚ C)

Table 10.2: Heat Loss and Heat Transfer Conduction for five consecutive days

Day	Average Heat Loss (W/h)			Average Heat Transfer by Conduction (W)		
	At 1.30 pm	At 2.30 p.m.	At 10.30 pm	At 1.30 pm	At 2.30 p.m.	At 10.30 pm
1	9.67	9.63	9.56	9.90	9.86	9.78
2	9.66	9.68	9.54	9.89	9.91	9.77
3	9.62	9.63	9.53	9.85	9.86	9.76
4	9.75	9.74	9.53	9.98	9.98	9.76
5	9.74	9.65	9.54	9.97	9.88	9.77

According to Table 10.2, the average amount of Heat Loss through cellulose and average Heat Transfer by conduction results in a small difference. This happened due to open conduit experimental roof structure that cause the natural ventilation. Heat losses can be transfer out easily by natural ventilation through the whole sample structure’s surfaces. Furthermore, the amount of heat losses per hour are lower than the average heat transferred, occurs due to amount of heat is stored left in cellulose.

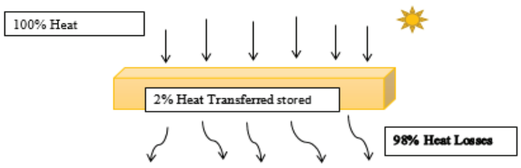

Figure 10.5: Illustration of Heat Transfer and Heat Loss

The average heat transfer by conduction through the cellulose is different at night. The R-Value can be changed up to 45% in which the difference between air humidity percentage between daytime and night. The permeability of algae in Nypa Frutican Rachis influence the absorption of moisture content on outer surface and forced the transferring of hot particle inside the cellulose to a cooler cavity (Outer surface) then freely transmitted to the atmosphere.

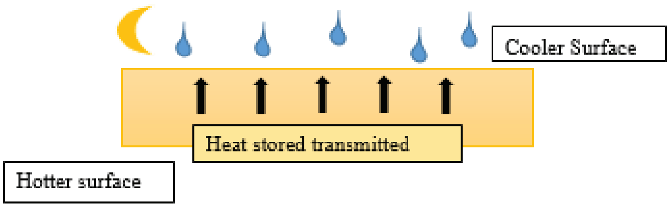

Figure 10.6: Illustration of Heat Transmitted at Night

10.4 CONCLUSION

The temperature at the outer surface is higher than the inner surface during 1.30 p.m. and 2.30 p.m. Meanwhile, at night, mostly the temperature is lower at the outer surface and higher at the inner surface. This proves that the presence of cellulose in Nypa Frutican Rachis help a house to achieve a thermal comfort. From the average amount of heat transfer and heat loss calculated, both parameters result in a small difference. This result would be more effective if an experiment conduct in a close volume attic. The amount of heat losses would be reduced due to less natural ventilation system and a limited airflow for the sample surface area. As a conclusion, the Nypa Frutican Rachis is suitable for roofing and insulating material but need a further enchantment for their physical properties to withstand the extreme climate such as heavy rain and storm. This study shows that the cellulose in Rachis could be alternative insulation in order to achieve thermal comfort house.

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